Trajectory Based Operations

Far-Term Concept
Proposed Trade-Space Activities

Environmental Working Group
Operations Standing Committee

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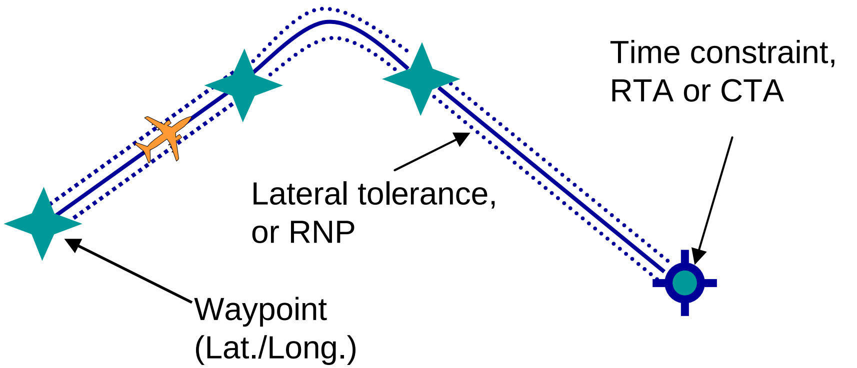
Purpose for this Presentation

- Outline Far-Term TBO concept as developed by JPDO Air Navigation Services and Aircraft Working Groups
  - Evolving from NextGen ConOps V2.0 (June 2007)
  - Consistent with FAA mid-term TBO implementation plans

- Introduce proposed FY10 - 11 ANS WG TBO activities
  - End-State TBO vision
  - Identify Tradeoffs in the Transition to TBO

What is a Trajectory?

"- a description of the movement of an aircraft, both in the air and on the ground, including position, time and, at least via calculation, speed and acceleration" (*ICAO Doc 9854)*



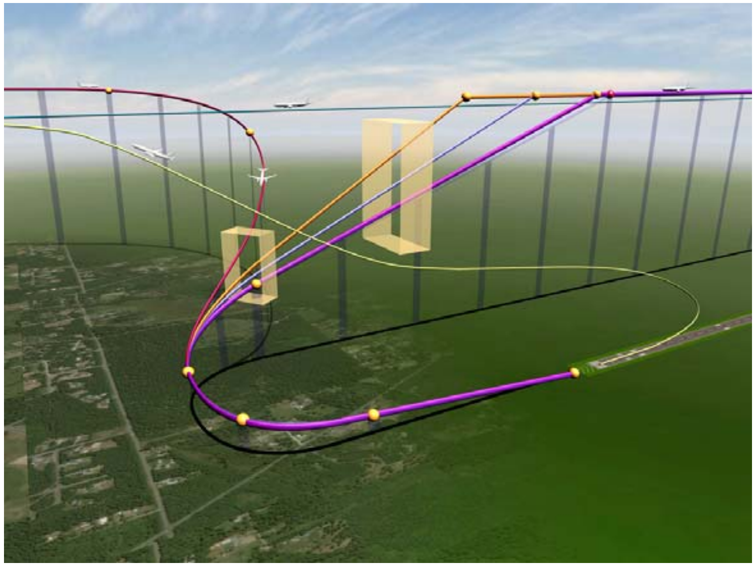
Horizontal position is usually expressed as lat./long. and may be derived from GPS or DME. Vertical position, or altitude, is derived from aircraft altimeters. Time expresses when the trajectory is executed

Each of the 4 trajectory dimensions is associated with a tolerance depending on aircraft performance

The specificity of a trajectory depends both on the aircraft and the operating environment

Trajectories are ground-referenced, so along-track prediction depends on local wind

A current FMS-equipped aircraft performs 2 - 3D trajectory operations (and possibly has some 4D capability)



The primary enablers and assumptions of TBO

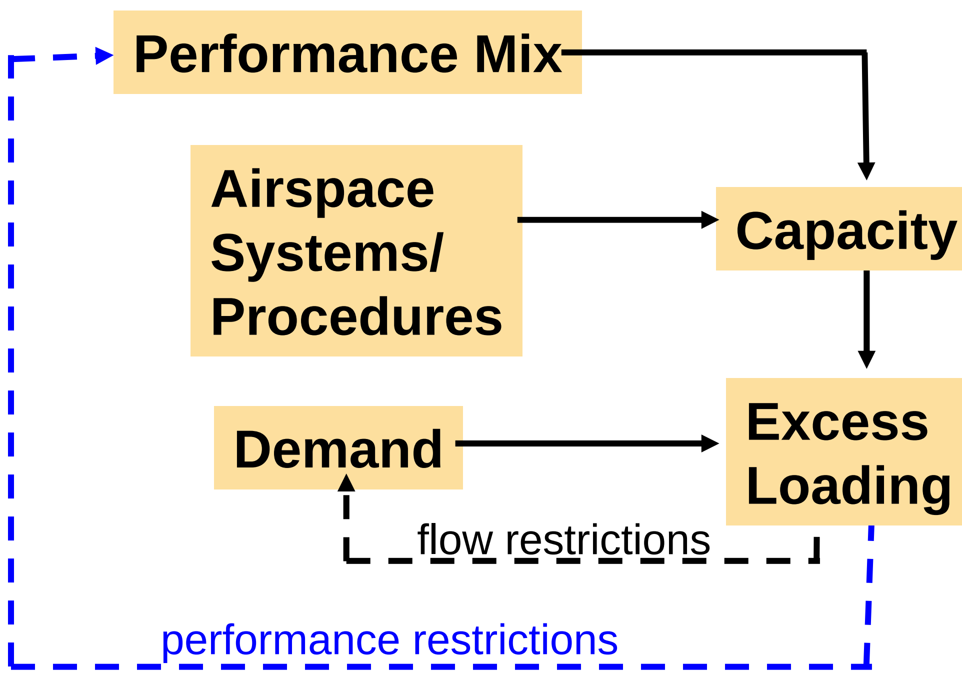
- All aircraft operating in managed airspace have cooperative surveillance (e.g ADS-B out) and RNAV/RNP
- All IFR, and some VFR, aircraft have an associated 4DT, either
  - generated on the aircraft and data-linked with the ATM systems
  - generated from a flight plan and turned into a 4DT by ATM systems
  - or possibly a combination of both
- TBO is the standard for planning and operations throughout the NAS, from very long term planning through flight execution to post analysis
- Data link and other advanced capabilities will be required for some operations and airspace (e.g. high altitude en-route, major terminals and metroplexes)
- Accommodating mixed performance is the design goal, with safety, capacity and productivity driving imposition of minimum performance requirements
- For safety and effectiveness, ATM systems must be the repository for <u>all</u> trajectories

TBO: How does it work?

The ANSP aggregates trajectory information for all aircraft into a demand forecast, which it prepares to satisfy, negotiating with flight operators and progressively refining the intended trajectory until flight execution time, then using that trajectory to safely manage the actual flight

When there is contention for resources (demand > capacity), the ANSP sets minimum performance requirements to increase capacity

Access preference is given to more capable aircraft because more can be handled with the same level of ATM resources - the philosophy of Performance-Based Operations



TBO in flight execution

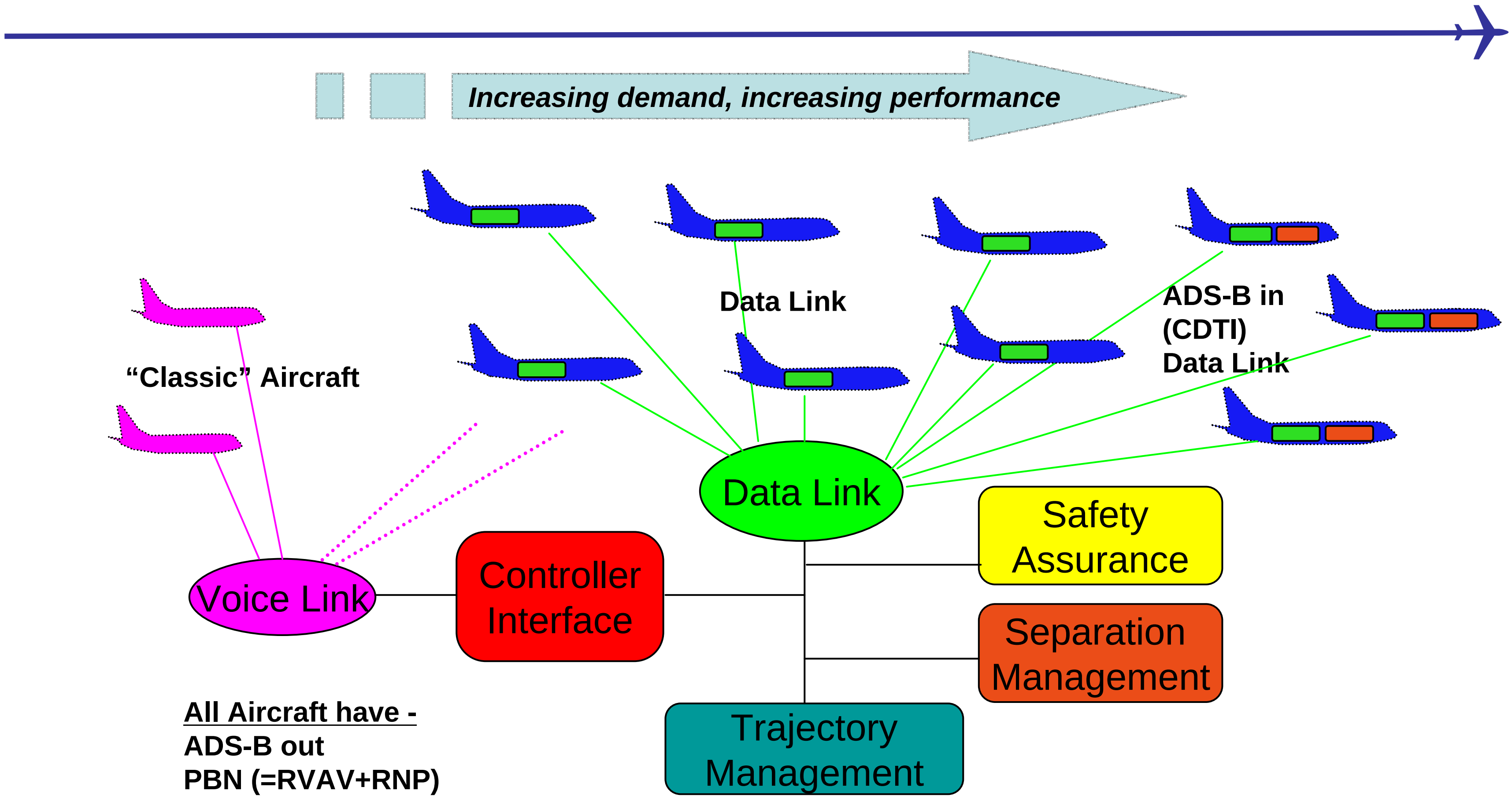
- ATM clearances that modify trajectories may be voice or data, depending on the aircraft and the operation
  - Performance level associated with each trajectory is set by ground systems and handled accordingly
  - Trajectory automation generates all clearances
    - Sends data link clearance with controller concurrence
    - Provides text for “closed” trajectory voice clearances to controller and tracks compliance

- Data link allows more complex clearances and revisions
  - 4D precision maximizes capacity of congested resources
  - Preferential access provided to more capable aircraft
  - Voice provides an exception mode

- Other aircraft are managed through voice communications
  - Nominally “closed” trajectories (e.g. 3-D path clearances), vectors by exception
  - Participation in TBO is enabled through RNAV/RNP and ATM automation

- Overall access and operational flexibility depends on participation in TBO, in accordance with the philosophy of Performance-Based Operations, or “Best Equipped, Best Served”

Illustrating TBO/PBO



- Automation tools allow the controller to manage aircraft in a mixed capability environment
- As demand increases, the ability to safely manage lower performing aircraft decreases
- In generally high demand or complex situations, lower performing aircraft may be excluded

Trajectory-Based Operations in ATM

Capacity Management

- Aggregate trajectories = demand forecast
- Better aircraft ATM performance (e.g RNP, data link) = more capacity
- CM process includes developing policies and rulemaking for Performance-Based Operations and Services
- Set required performance so that capacity > demand
- Over very long term (~decades), can create new capacity through new air and ground capabilities/infrastructure
- Over moderate term (~years), can expand existing capabilities to new locations
- Over short term (~weeks), capabilities are fixed, but can be allocated to different places (e.g. ANSP staffing)
- Planning process, including weather, is probabalistic over long term, becoming more deterministic in short term
- Uses high level trajectory information
- Very collaborative with flight operators allowing business trade-offs

Trajectory-Based Operations in ATM

Flow Contingency Management

- Operates when demand/capacity imbalances still exist after the Capacity Management process, often because of weather
- Results in much less disruption than today's TFM because TBO facilitates more flexible solutions optimized for affected aircraft
- Uses scheduling via CTAs as needed (similar to today's time-based metering), and route modification when necessary
- Reroutes aggregate trajectories if needed to avoid weather, congestion etc., and also to optimize for en-route winds
- Collaborative with flight operators, allowing prioritization of individual flights
- More deterministic than long term Capacity Management

Trajectory-Based Operations in ATM
Trajectory Management

- Operates just before and during a flight
- Must involve safe, “flyable” trajectories that
  - Ensure conformance with CM plan including FCM constraints
  - Are within aircraft performance limits
- Optimizes individual trajectories
- Positions and schedules aircraft for Super-Density or other Delegated Separation procedures
- Accommodates aircraft operator preferences to extent possible
- Includes managing complexity (>20 min. horizon)
  - Maintain maneuvering flexibility
  - Reduce probability of future aircraft conflicts
- Performs “strategic” conflict detection/resolution (~10-20 min. horizon) where appropriate

Trajectory-Based Operations in ATM

Separation Management

Enhancements, including reduced separation minima, will be enabled by TBO. NextGen envisions two distinct situations, both supported by trajectory-based automation and automated conflict detection -

- Aircraft intentionally flown close together, with separation ensured through nominally non-conflicting RNP trajectories, and with aircraft-based “blunder protection”
  - Multiple closely-spaced approaches
  - Aligned trajectories for en-route congestion, or “Flow Corridors”
- Solving conflicts that are a normal, but unintended, consequence of aircraft flying optimal trajectories
  - Time horizon for solving conflicts depends on aircraft involved and the operation
  - Automation suggests optimal resolution maneuvers

Trajectory-Based Operations
ANS WG proposed activities FY10-11

End-State TBO vision

- TBO as a spectrum of performance levels from basic datalink of clearances to to high-end automation of precise trajectory management
- Avionics requirements for TBO, including performance “windows”, vertical precision, broadcasting intent, CTA/ETA/RTA precision and negotiation
- Airspace design and classification dependencies for various levels of traffic density and complexity
- UAS operations
- Security and Environmental aspects of TBO

Identify Tradeoffs in the Transition to TBO

- Avionics requirements for range of TBO performance levels
- Capacity benefits and constraints in a mixed equipage environment
- Progression from assisted to fully automated trajectory negotiation
- Balance environmental goals with capacity needs
- Balance security requirements with capacity and operator flexibility needs

Trajectory-Based Operations
Take Away Messages

Much remains to be done to define TBO and how it will really work in the far-term

- Converging on holistic TBO concept, but still qualitative
- Trade-space and other studies will frame and begin to quantify the concept

Regard TBO as the enabler for both capacity and environmental benefits

- Higher ATM performance is correlated with better environmental performance

Early "NowGen" capabilities presented at this meeting are important to inform the far term TBO concept